(1) Technical Challenges

(a) In the past year we have conducted 143 interviews with people around the country in the stormwater ecosystem. This includes property developers and consulting civil engineers. From these interviews we learned what the customer needs in a stormwater management device. First and foremost the device needs to reduce the peak of the runoff hydrograph to meet regulatory requirements. Our product will do this by collecting and infiltrating stormwater from the impervious surfaces on the site throughout the soil around the site. Because the product is a system of tubular devices it has the ability to spread the water out over a larger area then current methods. The device also needs to be easy to design and specify to help the engineers complete their job as efficiently as possible. To meet this need, design software will be developed to help the engineers determine the composition, number, and layout of the devices required for a project.

The stormwater management device also needs to be straightforward to install and maintain. Straightforward installation will help ensure that the installation is done correctly so the device can function as designed. This is achievable because onsite wastewater (septic) installers currently practice the excavation requirements the product needs and the units are modular so large equipment is not required for placement. Easy maintenance is important so that the device will be maintained properly so it continues to function as designed. Maintenance for this device would include routine landscaping upkeep and occasional vacuuming of the sedimentation basin placed at the head of the device to ensure the device does not clog with sediment or other debris.

From the interviews, we learned that stormwater management on any given project site can account for more than a quarter of the project cost and an even larger portion of the design time and cost. For example, on a $2 million build, we were told that $500,000 would be spent on the storm sewer alone. Additionally, certain common management methods such as detention or retention basins can take up 10% of a site, reducing the amount of land on a site available for development. By having a stormwater management method that streamlines design, increases the percentage of a site that is developable, and includes other benefits such as aesthetics and positive environmental impacts, like base flow and ground water recharge, we do not have to try and undercut competing solutions' prices. Instead, we can use value based pricing for our product and still end up with an overall lower cost for the property developer who is footing the bill.

(b) There are a large variety of competing technologies in the stormwater management area, including surface detention/retention basins, swales, and below ground detention systems, which utilize a manufactured system to manage the stormwater. Basins are a common method of stormwater management and reduce the peak of the runoff hydrograph from the newly impervious surfaces by holding and slowly releasing the collected water. As mentioned above, one of their major downsides is the large amount of space they take up on a site. They are fairly easy to design and there are some freely available software programs that can be used to determine the size of basin required. They are constructed by excavating the volume of soil required to produce the necessary size basin and then fitted with piping to allow for the release of collected water. If it is a detention (dry) basin it will need to be mowed regularly and can be an eyesore according to some property developers. If it is a retention (wet) basin, landscaping maintenance will also need to be performed and work will be done to ensure that leaks are fixed and make-up water is added during dry periods. Sometimes retention basins will be used as water features and treated like an amenity in certain developments. The cost of the basin itself may be less expensive than the cost of our device, but the increase in developable land and reduced maintenance of our technology more than make up for it.

Swales reduce the peak hydrograph by collecting runoff from impervious surfaces and by slowing and infiltrating the water. The infiltration only occurs locally with swales. Design of swales is fairly straightforward and once again there are some software programs that can assist engineers in the design process. The construction of swales can be a bit more challenging because swales need to be constructed on a contour line and the soil cannot be overly compacted, thus grading is important. Because the water in the swale must evaporate or infiltrate in a few days, they may need to be quite large or many may be need to be constructed on a site. Also, maintenance is a big issue as the vegetation within the swale needs to be taken care of every few months and sediment that collects will need to be removed when it takes up a quarter of the swale's volume. Much like the surface basin, the cost of swales may be cheaper up front, but the decrease in land devoted to stormwater management and lessened maintenance and installation requirements make our technology more cost effective

Below ground detention systems can be composed of pipes, arched chambers, vaults, or attenuation crates. Plastic, metal, and concrete are all used to make these devices. They work like the surface basins to reduce the peak of the runoff hydrograph in that they hold water and slowly release it. Some can include infiltration aspects, but it is localized and with the extensive land work required, the soil structure can be impacted and reduce the soil's ability to infiltrate water. This solution is often used for large projects in urban areas where a lot of water needs to be managed and where land is expensive. Installation and maintenance requirements and the process followed depend upon which system is used. Smaller pipes, chambers, or crates made of lightweight materials can be placed by hand, but larger and heavier devices require equipment in order to be placed. These units are often placed in large excavations and surrounded with gravel and geotextile fabric. Maintenance is more difficult for below ground systems than above ground systems such as basin and can involve vacuuming out sediment from the units themselves or from a pretreatment device. Design and installation services are provided by some of the companies with below ground detention systems. These units can be placed below parking lots or vegetation. The major downside of this solution is the cost of the product, the extensive excavation required for installation, and the lack of environmental benefits. The shallow excavation and environmental benefits of distributed infiltration make our technology a superior solution.

(c) Our technology and the competing technologies all reduce the peak of the runoff hydrograph. However, the way our device reduces the peak, how the engineer designs it, how much space it takes up, how it is installed, how it is maintained, and the resulting overall net stormwater project cost sets it apart.

Compared to surface basins, our device would spread the collected stormwater out over a larger area and allow it to infiltrate into the surrounding soil instead of being slowly released to a storm sewer or stream. Both methods have software options to assist engineers in designing the solution. Basins take up large amounts of land and do so in one location. Our technology would take up a smaller area and the area that is required could be partially under already planned landscaping and could be spread out around a site. Excavation is required for both methods of installation. Basin excavation can be conducted by any construction or excavation company, while an on-site treatment (septic) installer will be required for our device's installation. Excavation will be concentrated in one area for the basin, but with more excavation required. Maintenance for both methods includes mowing and landscape management, but additional work is required for retention basins, including fixing leaks and adding make-up water. Our technology will have a higher equivalent cost than a basin, but allowing for more developable land will more than offset this increase for the property developer.

Swales work to infiltrate water much like our device, but our device works to spread the infiltration out over a larger area. Software is available to assist with swale design and with our device's design. Water in the swales must be evaporated or infiltrated within a few days of the rain event, so several swales may be required to manage the stormwater volume from a site. This can result in a much larger footprint than our device requires. Land work is required for the installation of both of these stormwater management methods. Both installations must be careful not to impact the soil structure and require precise slope construction. The biggest difference between the two is that swales must be placed on the contour to function properly and our technology does not require that. Both require landscaping maintenance and sediment removal. However, the swale requires more maintenance overall and more labor-intensive maintenance. Like the surface basin, the initial cost may be less for a swale than a system of our devices, but the lesser space requirement and the lower maintenance requirements make our technology a more economical choice.

Below ground detention systems work much like surface basins and slowly release the collected stormwater. Some have an infiltration aspect, but not to the extent of our technology. Some companies that supply these systems also provide design assistance or software, like our company will. Our technology and below ground detention systems can both be placed below vegetated areas, but the detention systems can also be placed below parking lots. More excavation is required to install the below ground detention systems than to install our technology. Heavy machinery is also required for large installations of below ground detention systems. Maintenance on the surface is very similar between the two systems, but sediment removal in the below ground detention systems can require specific equipment and can be a more involved process, depending on the system, than sediment removal from the sedimentation basin placed ahead of our devices. The cost of the below ground system and its installation are greater than those for our technology.

The increase in developable land, the increased aesthetics, the ability to mimic natural processes, a streamlined design process, and the ease of installation and maintenance allow our device to generate an overall more cost effective and environmentally focused solution.

(d) Our technology provides various environmental benefits in addition to its primary benefit of reducing the runoff peak discharge from a site. By infiltrating the stormwater that runs off from a site, base flow that supports healthy streams and aquatic ecosystems is created, mimicking the pre-development hydrology. The ground water table is also recharged and by reducing overland flow, overland transportation of pollutants is reduced as well. This new subsurface flow can also remove some pollutants in the water as it makes its way down to the water table. All of these benefits come from mimicking natural processes. In addition to water cycle benefits, lifecycle costs and benefits need to be considered whenever a technology is being developed. The materials that make up our technology include geotextile fabric, developed for the conditions we will be placing it in and with long-term durability in mind, and aggregate, sourced regionally. If for some reason the device had to be removed or the site was redeveloped, the aggregate could be withdrawn from the device and repurposed or recycled through a sorting process. This would only leave the geotextile fabric as a true waste product, which would result in a small volume of additional waste in the landfill. The product's construction will not require highly technical machinery or large energy expenditures. It will primarily consist of machines to cut fabric, dispense aggregate, and sew the device shut. The manufacturing process will be set up to be as time efficient as possible to reduce the amount of time lights, heat, air conditioning, and other utilities have to be running at the manufacturing facility.

Material waste will be kept to a minimum by making sure the fabric is cut efficiently and by using the fewest number of geotextile fabrics and aggregates as possible to get the required range of solutions. Sourcing the aggregate close to the manufacture and installation site reduces the transportation required, thus reducing the overall energy cost of the product. The geotextile fabric is considerably lighter than the aggregate, so even though it will have to be shipped farther than the aggregate, the transportation energy requirements per device will be kept to a minimum. Excavation required by the solution will be as minimal as possible and will utilize lightweight machinery. The lightweight machinery limits soil structure disturbance and uses less fuel than heavier machinery. Minimizing the excavation limits the fuel required as well. An additional lifecycle benefit for our device would be to use waste concrete from demolished buildings, bridges, or roads as aggregate within the device, reducing volumes of waste being sent to landfills. Only recycled concrete not expected to leach products into the runoff would be utilized. The lifecycle costs for the device include the energy used to acquire the aggregate from its natural state and the negative environmental impacts from using fossil fuels.

The PI, Ms. Trauth, will be responsible for fleshing out significant detail about the Life Cycle Assessment during the Phase I research and testing. She will do so by researching leaching components and levels in different concretes, learning more about aggregate manufacturing processes and excavation machinery, calculating utility costs for a theoretical manufacturing facility, beginning initial design of manufacturing equipment for the device, and learning about a variety of geotextile lifespans and durability levels.

(2) Market Opportunity

(a) We determined our target market by first looking at the land development industry. A 2017 ibisworld.com report stated that the total land development revenue in the United States was $11.4 bn. Through our interviews we learned that 25% of a development project's budget can go towards stormwater management. Taking 25% of the total land development revenue gave us a total addressable market of $2.85 bn. To determine our served available market we wanted to consider what would be a good initial location to enter the market. We considered a variety of areas where there was a high regulatory demand for a product like ours. One example is the State of California. In 2015 California accounted for 13.5% of the United States' GDP. Assuming that they accounted for a similar percentage of the total land development in the country we calculated the served available market is $390 mn. Finally, the target market was determined by finding out that 63% of Californians live in communities of over 10,000 people, which require stormwater management. This gives us an initial target market of $245.7mn.

(b) There are two aspects of our product's market opportunity that needed to be validated. The first was, does stormwater have to be managed and the second was, are the current solutions satisfactory. The first aspect is validated through regulatory requirements in the Clean Water Act and the Phase I and Phase II implementing regulations, requiring management of stormwater runoff for post-development conditions; local regulations may require reducing the peak discharge to what it was before development. Reducing the peak discharge can be accomplished through a variety of stormwater best management practices (BMPs), which brings us to the second aspect of the market opportunity. Are the current solutions satisfactory? By conducting 143 interviews over the past year with engineers, regulators, property developers, installers, and other stormwater management technology companies, we determined that the current methods work to meet the current requirements but there is a desire for different and better solutions, especially as infiltration and low impact development begin to be preferred and sometimes required. We also learned about other aspects a BMP needs to provide in order to have a complete solution. These include easy maintenance, straightforward installation and design, efficient use of space, and to be at least somewhat aesthetically pleasing. This showed us that the second aspect of our product's market opportunity is validated as well.

(c) The main driver for selling to our target market is meeting regulatory requirements. In addition to requirements in the CWA, some states, such as California, and local governments have implemented more stringent stormwater management requirements. While speaking to a regulator for the San Diego County Regional Airport Authority, we learned that there is a growing focus towards managing stormwater on site and utilizing a hierarchy of BMPs, with reuse and infiltration as the top two methods. Although it is the main driver, regulation can also be a barrier to our selling in the target market. Even though this product is not focused on quality improvements, which would lead to a much more rigorous regulatory process, the installation of our devices needs to be approved on project plans. Test sites and the data collected from these sites will be imperative in proving to regulators that our product meets their criteria and manages the stormwater discharge from developed sites appropriately. Another barrier to selling to our target market will be competing technologies and methodologies that are already in practice and which engineers and regulators are already familiar with. Education on the benefits and methodology of our product, test sites, and data will help us overcome this barrier.

(d) Through our interviews we learned a lot about whom our customers are and what motivates them. There are two aspects to our customer because the property developer pays for the physical product, but they install what the engineer specifies. Interviews we conducted with property developers told us that they rely on the professional judgment of the engineers to specify practices to meet the technical and regulatory requirements. Therefore, we need to reach and engage with engineers. The engineering archetype is a licensed professional civil engineer who works at a consulting firm on the water and site components of development projects. They are probably 30-50 years old and at the point in their career where they are in charge of the projects they work on and have the authority on those projects to make choices on what methods and products are used. They are also interested in trying new and possibly better products and processes to solve their engineering problems. The budget on the projects they work on varies but can be hundreds of thousands of dollars. They are motivated by regulation, serving their clients, and reducing negative environmental impacts and are influenced by professional organizations such as the American Society of Civil Engineers and their colleagues.

Our business model is based off of work we did with the Business Model Canvas in the I-Corps Program. We will sell systems of physical units to property developers working on sites of one acre or more in communities of 10,000 people or more. Engineers will specify these units and will purchase a subscription to use our software to design the system efficiently. Property developers and engineers will want to use our product because it will meet regulatory requirements, allow for additional developable land on a site, create a positive environmental impact, be aesthetically pleasing, decrease design time, be straightforward to install, and easy to maintain.

(e) Our competition falls into two different categories: (1) non-proprietary best management practices (BMPs) and (2) proprietary or manufactured BMPs. Examples of non-proprietary BMPs are basins and swales. Many non-proprietary BMPs in use are widely accepted by regulatory bodies and their design and installation are often outlined in manuals created by the regulatory bodies. They are not often composed of expensive components but their installation and maintenance can sometimes be difficult and they can have a large footprint on a site. A large footprint reduces the amount of developable land on a site thus reducing revenue.

An example of a proprietary or manufactured BMP is a below ground detention system. Manufactured BMPs for quantity management are also generally accepted, once they successfully demonstrate that they work on test sites. The regulating agency is not likely to provide design guidelines for them. These devices can be expensive but the companies that produce them often provide design and installation information. They typically are used for their smaller footprint on sites. Maintenance and installation vary depending on which product is used but it can be more straightforward than some of the non-proprietary BMPs. By the time our product enters the market we expect more products and methods that try to mimic natural processes to be available. As communities and their regulating bodies move more towards low impact design and utilizing more natural processes, the industry will adapt and move in that direction as well. We will be at the forefront of meeting this new demand in the stormwater industry.